



Supplement of

Pleniglacial dynamics in an oceanic central European loess landscape

Stephan Pötter et al.

Correspondence to: Stephan Pötter (stephan.poetter@geo.rwth-aachen.de)

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SUPPLEMENTARY MATERIAL

S1 Supplementary material regarding sedimentology



Figure S1: Tectonic offset of Holocene decalcification boundary approx. 1 km northwest of the Siersdorf LPS.



Figure S2: Test core recovered approx. 6 m from the sampled exposure. Top left: location of drilling site in relation to sampled exposure. Other photographs: recovered drill cores with depth markings.



Figure S3: Grain size distributions for the stratigraphic units of the Siersdorf LPS. (a) Sketch of the Siersdorf LPS. (b)-(g) grain-size distirbution frequencies for the respective stratigraphic units.



Figure S4: Photograph of the gyttia at the Ringen exposure in the Middle Rhine Valley.



Figure S5: Grain size distributions of unit I in Siersdorf (SID, red line) and the gyttia at Ringen (RGE, black line).

S2 Detailed luminescence dating methodology

S2.1 Dose rate determination

For dose rate determination, bulk samples were taken from the same stratigraphic units as the OSL samples, respectively. After drying at 50 °C and homogenising, the samples were canned and stored for one month. Uranium-, thorium- and potassium- contents were measured in the CLL by applying high-resolution gamma spectrometry (Ortec PROFILE M-Series GEM Coaxial P-type HPGe Gamma-Ray Detector; Tab. 1 in main text). Dosimetry and age calculation were conducted in the DRAC environment (version 1.2; Durcan et al., 2015) by using conversion factors from Liritzis et al. (2013). For assessing the internal dose rate of polymineralic samples, the internal potassium content was estimated to 12.5 ± 0.5 %, following Huntley and Baril (1997). Grain-size attenuation factors for alpha and beta doses were adopted from Bell (1980) and Guérin et al. (2012). To account for the effects of etching on the beta dose, attenuation factors of Brennan (2003) were used. For polymineralic data, a-values of 0.101 ± 0.014 were adopted from Schmidt et al. (2018), while 0.036 ± 0.003 was assumed for quartz samples (Kreutzer et al., 2012a). Water contents were determined in-situ based on water loss after drying at 50 °C. However, as these likely underestimate the hydromorphic conditions at the study site, we used water contents of 15 ± 5 % which are typical for European loess (e.g., Pécsi, 1990; Klasen et al., 2015). Cosmic dose rate calculation followed Prescott and Hutton (1994), including sampling depth, geographical position and altitude above sea level, as well as bulk density, adopted from Lewis and Sjöstrom (2010).

S2.2 Equivalent dose (D_e) determination

Luminescence measurements were performed on an automated Risø TL/OSL DA 15 reader (DTU Nutech, Roskilde, Denmark) equipped with a calibrated 90 Sr/ 90 Y beta source. Discs were prepared by pipetting a suspension of 1 mg sediment and 0.2 ml deionised water and drying them afterwards. Polymineralic fine-grain samples were stimulated for 200 seconds by using infrared diodes (870 nm, FWHM = 40) and an interference filter (410 nm). To obtain a polymineral signal not (or not significantly) affected by anomalous fading, a post infrared infrared (pIRIR) stimulated luminescence protocol was applied with a second stimulation temperature of 290 °C following

Thiel et al. (2011). Furthermore, fading measurements were conducted on five aliquots per sample following Auclair et al. (2003). The suitability of the pIRIR₂₉₀ protocol was ensured by dose recovery and residual measurements on three aliquots per sample (Fig. S2.1). For this, aliquots were artificially bleached in a Hönle SOL2 solar simulator for 24 hours and in case of dose recovery experiments irradiated prior to the first stimulation with beta doses in the range of the natural doses, i.e., ~70 Gy (for SID L1–L3) and ~140 Gy (for SID L4–L6). The protocol was designed with 20 s pause before the second IR stimulation to account for unintended transfer of charge. Four regenerative doses were incorporated in the protocol to construct the dose-response curves. A subsequent zero measurement was used to test for recuperation while the repetition of the first regenerative dose allowed to determine the recycling ratio. For equivalent dose (D_e) determination, the integrated signal was limited to the initial 11 s (after 20 s pause), subtracted by a background of the final 37 s.

For quartz fine-grain samples, the reader was equipped with U340 filters. A conventional SAR protocol was applied (Murray and Wintle, 2000) with blue LED stimulation for 40 s at 125 °C, a preheat at 200 °C and a cutheat at 180 °C (Fig. S2.2). The preheat temperature was chosen based on a preheat plateau test with preheat temperatures between 180 and 280 °C (Fig. S2.3). The suitability of the protocol was verified by running a dose-recovery test for each sample (Fig. S2.3). Test doses were adjusted to 20-30 % of the natural doses and at the end of each measurement sequence, IR diodes were switched on to test for any feldspar contamination. As for polymineralic fine-grain measurements, recuperation and recycling ratio were investigated by the design of the measurement procedure. To retrieve mainly the fast component of the detected luminescence signal, only the first 0.8 s minus the final 8 s background were integrated into D_e determination. The existence of a dominating fast component, which is required for applying the SAR protocol (Jain et al., 2003), was tested using CW curve deconvolution implemented in the *R-Luminescence* package (Kreutzer et al., 2012b).

Dose-response curves were fitted exponentially to provide a saturation curve similar to natural conditions. Error calculations included a measurement error of 1.5% that was incorporated in curve fitting. Aliquots were accepted if error ranges of recycling ratio and maximum test dose error did not exceed 10%, and if the natural test dose signal was at least three standard deviations larger than the background. Since scatter in dose distributions of fine-grain samples is completely absent (reflected by over-dispersions around zero), the arithmetic mean plus standard deviation was chosen to calculate burial doses.

S2.3 Luminescence laboratory experiments

S2.3.1 Suitability of potassium feldspar data

All polymineralic fine-grain samples show bright post-IR₂₉₀ signal intensities, for example with several 10,000 counts after ~43 Gy test dose stimulation (Fig. S2.4). Dose recovery and recycling ratios are all within the acceptable 10%-error range and recuperation is around 2 % of the natural dose. Laboratory residuals vary between ~5 and ~7 Gy, which is less than 4% of the natural doses. Thus, the pIRIR₂₉₀ protocol was found to be adequate for D_e measurements. Fading rates of ~1–1.5 %/decade indicate that fading is not significant and does not need to be corrected for (Buylaert et al., 2012).

S2.3.2 Suitability of quartz data

The signals of the quartz samples are even brighter than the feldspar signals and are dominated by the fast component (Figs. S2.5 and S2.6). For all preheat temperatures between 180 and 280 °C, preheat plateau tests for

samples SID L1 and L5 indicate a dose plateau, recycling ratios within the acceptable $\pm 10\%$ -error range and low recuperation of ~0.7 % (SID L1) and 1.3 % (SID L5; Fig. S2.2) of the natural dose. For subsequent measurements, a preheat temperature of 200 °C was chosen and the adequate performance of the SAR protocol is reflected by dose recovery ratios of 0.95–1.0 (Fig. S2.2).



Figure 6: Performance of the pIRIR290 protocol used in this study.



Figure S7: Results of preheat plateau tests on fine-grain quartz samples SID L1 and SID L5. A preheat temperature of 200 °C (shaded in grey) was chosen for subsequent measurements.



Figure S8: Dose-recovery ratios for quartz fine-grain samples of this study.



Figure S2.4: pIRIR₂₉₀ decay curve after ~43 Gy test dose stimulation (a) and dose-response curve (b) for sample SID L4. The integrated signal (initial 11.1 s after 20 s pause) is highlighted.



Figure S9: Quartz decay curve after ~43 Gy test dose stimulation (a) and dose-response curve (b) for sample SID L4. The integrated signal (initial 0.8 s) is highlighted.



Figure S10: Quartz decay curve of sample SID L4 with the contributions of the different signal components. The fast component (component 1), which is used for dating, since stable and easy to bleach, clearly dominates the first \sim 2 seconds of the shine down curve.



Figure S11: Equivalent dose distributions of polymineralic fine-grain samples shown as Abanico plots.



Figure S12: Equivalent dose distributions of quartz fine-grain samples shown as Abanico plots.

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